

Search for Variable Sources Using Data of “Cold” Surveys

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We search for variable sources, using the data of the surveys conducted on the RATAN-600 radio telescope in 1980–1994 at 3.94 GHz. To test the radio sources of the RCR (RATAN Cold Refined) catalog for variability, we estimated the long-term variability indices V of the studied objects, their relative variability amplitudes V_χ , and the χ^2 probabilities p . Out of about two hundred considered sources, 41 proved to have positive long-term variability indices, suggesting that these sources may be variable. Fifteen objects can be considered to be reliably variable according to the χ^2 criterion $p > 0.98$, three of these sources have χ^2 probabilities $p \geq 0.999$. The corresponding probabilities for six sources lie in the $0.95 < p < 0.98$ interval, and those of the remaining 20 objects in the $0.73 \leq p < 0.95$ interval. Twenty-four of 41 objects are variable or possibly variable in the optical range, and five objects are known variable radio sources. We construct the light curves and spectra for the sources with positive long-term variability indices.

1. INTRODUCTION

Many radio sources exhibit flux density variations when observed at different epochs. This variability is due to both external (scintillations) and internal factors, which are associated with the radiation generation processes in the source itself.

Variable radio sources are associated with different classes of objects, and their

variability has different characteristic time scales. Variable radio emission is observed in active galactic nuclei (AGN), microquasars, pulsars, and stars. Some AGNs exhibit intraday variability (IDV) due to the scintillation of their very compact components, caused by inhomogeneities of the intervening medium between the observer and the object. Flux density variation amplitudes may vary from several percent to several tens of percent.

On time scales of one to several months, the variations of synchrotron emission often

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correlate with those of optical and/or x-ray radiation because of the nonuniform accretion rate and interaction between the jet and the ambient medium in the immediate vicinity of the nucleus. Variability on time scales of several years may be due to more substantial changes in the accretion rate, heating of the matter, and energy processing in the accretion disk. Long-term variability of very bright AGNs with fluxes above 1 Jy is a subject of systematic studies; however, few such studies have been carried out for the population of fainter AGNs because of the lack of observational data. At the same time, the study of radio variability of the sources with weak flux densities may prove to be a unique tool for investigating the evolution of AGNs and the nature of this phenomenon. Note that almost all the sources brighter than several mJy observed in 1.4 GHz surveys are AGNs.

Variability studies performed by monitoring objects from the lists of bright sources are carried out in many observatories worldwide, including the Special Astrophysical Observatory of the Russian Academy of Sciences, where such programs are performed on the RATAN-600 radio telescope. Starting from 1998, long-term sets (from one to three months) of multifrequency observations are carried out at the Northern sector of RATAN-600

to study variable objects. Bright discrete radio sources with flat spectra are being investigated mainly. Such sources show variations on time scales ranging from several tens of minutes to several decades. The results of these long-term studies are reported, e.g.,

At the end of the 20-th century, an approach was developed that uses the data of radio surveys to search for variable radio sources. As an example of the application of this approach, we can mention the study by De Vries et al. (author?) [11], who used FIRST data (for the period from 1995 to 2002) in the vicinity of the South Galactic Pole to extract a sample of 123 radio sources with flux densities from 2 to 1000 mJy, found to exhibit substantial variations at 1.4 GHz over a seven-year long time interval, and a recent study by Thyagarajan et al. [12], who searched FIRST survey data to find 1627 variable and transient objects with flux densities up to 1 mJy, characteristic variability time scales ranging from several minutes to several years, and flux variations ranging from 20% to a factor of 25.

De Vries et al. [11] found that (1) the sample of variable sources contains a substantially greater fraction of quasars than the control sample with nonvariable sources, (2) variable sources are almost twice more often identified with SDSS than nonvariable

sources, (3) the number of quasars is almost five times greater than that of galaxies, and (4) the two samples do not differ significantly in color.

In this paper we continue the research that we initiated in [13], i.e., a search for variable radio sources based on the data of the “Cold” surveys [14] carried out at 7.6 cm on the RATAN-600 radio telescope. We test the sources for variability, using the criteria, including statistical ones, described by Majorova and Zhelenkova [13].

In our previous paper [13] we used the objects from the RCR (RATAN Cold Refined) [15] catalog selected using certain criteria to derive the calibration curves and perform a detailed analysis of the errors of the measured source flux densities in each of the considered surveys. To assess variability, we compute the long-term variability index, the probability of variability by χ^2 , and a number of other parameters characterizing variability. In this paper we search for variable objects, using a larger source sample compared to the one used in our previous study [13].

2. USE OF SURVEYS TO SEARCH FOR VARIABLE SOURCES

The periodicity, sensitivity, and observing frequencies effect the types of variable and transient sources detectable in the conducted

surveys.

The radio source detection threshold of the “Cold” experiment conducted in the 1980’s at RATAN-600 at a frequency of 3.94 GHz [14, 16] was equal to about 10 mJy [17, 18]. The RC (RATAN Cold) catalog based on this survey was later refined by conducting a series of surveys in 1987–1999. These surveys were performed at the same declination¹ and frequency as the “Cold-80” survey, and had a sensitivity limit of about 10–15 mJy. The results of the reduction of these surveys were reported in [15, 19–21]. Soboleva, Majorova, and Zhelenkova [15] published the RCR-catalog of objects observed within the framework of the 1987–1999 surveys in the band $7^{\text{h}} \leq \text{RA} < 17^{\text{h}}$ as well as the results of a new reduction of the data of the “Cold-80” experiment.²

It was found, after the identification of RCR catalog objects [22, 23], that practically all RCR sources are sufficiently bright for a search to be made for long-term variability of AGNs with flux densities $F > 10\text{--}15$ mJy as well as for possible transients.

To this end, in this study we use the data of 7.6-cm surveys conducted in 1980, 1988,

¹ The surveys were made at the declination of SS 433 ($\text{Dec}_{1980} = 4^{\circ}57'$).

² Spectra of RCR sources can be found at <http://www.sao.ru/hq/len/RCR/>

1993, and 1994.

A certain advantage of using surveys to study the variability of radio sources is that during the survey the antenna of RATAN-600 radio telescope is focused on a certain elevation and its configuration remains practically unchanged in the process of observations. This reduces the errors due to the realignment of the antenna, and this is especially important for the determination of flux densities of sufficiently faint sources.

Furthermore, because of the “fan-shaped” configuration of the power-beam pattern (PBP) of RATAN-600 when operated in the mode of single-sector observations [24–28], a large number of sources are found simultaneously within its field of view. Thus at 7.6 cm more than 30000 NVSS objects [29] pass within the field of view in a single crossing of the sky. Increasing the integration time via repeated crossing of the same sky strip allows increasingly fainter radio sources to be reliably studied.

Note that the data of the 1980–1994 surveys can be used to study the long-term variability of radio sources on time scales of several years. Such variations are known to be due to nonstationary processes in active galactic nuclei.

3. SAMPLE OF RCR CATALOG SOURCES USED TO SEARCH FOR VARIABLE OBJECTS

In this paper we search for variable sources, using the sample of RCR-catalog radio sources with flux density data available at three or more frequencies. We already studied 80 such sources in our earlier paper [13]. Recall that out of 550 RCR-catalog objects, 245 have flux density data available only for two frequencies (1.4 GHz [29] and 3.94 GHz [15]). These are mostly faint radio sources with flux densities below 30 mJy.

Whereas in our previous study [13] we derived the calibration curves based on bright objects with steep spectra with minimum scatter of data points in order to minimize the contamination by variable sources,³ in this paper we do not use criteria imposing restrictions on the spectral index, compactness, morphological structure, etc.

As the initial data for the analysis of the variability of RCR-catalog sources, we use several-day average observational records that have undergone primary reduction [19]. After background subtraction

³ Steep spectrum radio sources rarely exhibit variations at frequencies above 1 GHz except for the objects found to host a compact component, which is responsible for flux variations [30, 31].

we identified the sources on the averaged scans via Gaussian analysis. We used standard software for the reduction of radio astronomical observations [32]. A detailed description of the technique used to reduce survey data has been published in [13, 15], and the technique of searching for variable sources using the data of RATAN-600 surveys can be found in [13].

When analyzing the sources in order to select the variable ones, we studied objects with 3.94-GHz flux densities $F \geq 15$ mJy, which are easily identifiable in the records and are unblended with other sources.

From the entire list of RCR sources, we selected about 200 objects that were observed in two or more sets of the “Cold” surveys and meet the above requirements.

Figure 1 shows the histograms of the distribution of flux densities F (the top panel) and spectral indices α (the bottom panel) for this source sample.⁴ About half of the objects in this sample have flux densities below 50 mJy, and 51 sources have flux densities above 70 mJy. The median spectral index α of the objects considered is equal to -0.61 .

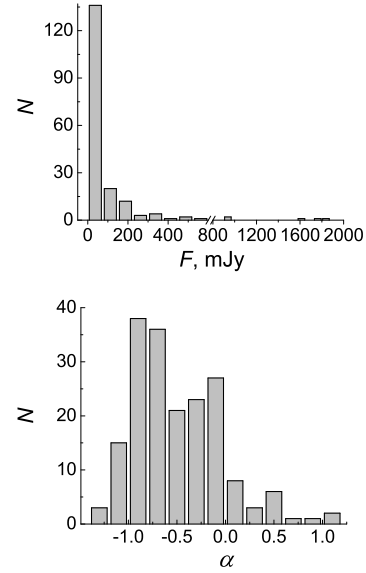


Рис. 1. Histograms of the distribution of flux densities F (the top panel) and spectral indices α at 3.94 GHz (the bottom panel) for the considered sample of RCR objects.

4. REVEALING VARIABLE OBJECTS AMONG THE SOURCES

We use several criteria to select possibly variable sources. In particular, we estimate the coefficients V_R [11] and V_F [33], and the long-term variability index V [10] for each object of our sample.

We compute the coefficients by the

⁴ Here α is the spectral index at 3.94 GHz.

following formulas:

$$V_R = F_i/F_j, \quad (1)$$

$$V_F = \frac{F_i - F_j}{\sqrt{(\sigma_i^2 + \sigma_j^2)}}, \quad (2)$$

$$V = \frac{(F_i - \sigma_i) - (F_j + \sigma_j)}{(F_i - \sigma_i) + (F_j + \sigma_j)}, \quad (3)$$

where F_i and F_j are the flux densities of the given source, measured in the surveys of the i -th and j -th cycles respectively, and σ_i , σ_j are the absolute root-mean-square errors of the inferred flux densities ($i, j = 80, 88, 93$, and 94).

The latter two criteria take into account the flux density measurement errors and therefore can be considered to be more reliable for testing the sources for variability. One of the source variability indicators is the positive estimate of its long-term variability index for at least two surveys.

We computed the flux densities F_i of radio sources, using their antenna temperatures T_a^i , determined from averaged records of the corresponding survey, and the calibration curves. For a detailed description of the derivation of calibration curves and selection of calibrating sources see [13].

We compute the absolute σ_i and relative RMS_i root mean square errors of the source

flux density in the i -th survey by the following formulas:

$$\text{RMS}_i = \sqrt{(\text{RMS}_i^{Ta})^2 + (\text{RMS}^k)^2}, \quad (4)$$

$$\sigma_i = F_i \times \text{RMS}_i, \quad (5)$$

where RMS_i^{Ta} is the relative root mean square error of the estimated antenna temperature of the source, and RMS^k is the relative root mean square error of the derived calibration curve.

$$\text{RMS}_i^{Ta} = \sigma_s / T_a^i,$$

where σ_s is the dispersion of noise in the sky strip runs of the survey considered.

The averaged RMS^k values based on the sample of calibrating sources for the 1980, 1988, 1993, and 1994 surveys are listed in Table 1 in [13].⁵

We considered the radio sources with flux density differences between different surveys exceeding the sum of the root mean square errors of the corresponding surveys to be possibly variable. The long-term variability indices of such sources are $V > 0$.

We found 41 sources in the considered sample (consisting of about 200 objects of

⁵ The relative errors RMS^k were averaged over the $-30' < dH < 30'$, $-15' < dH < 15'$, $-10' < dH < 10'$, and $-5' < dH < 5'$ intervals as well as over the sample of calibrating sources whose antenna temperatures in the records exceed $10\sigma_s$.

the RCR catalog) to have positive long-term variability indices V . Columns 1, 2, 3, and 4 of Table 1 list the coordinates of these objects (RA₂₀₀₀, Dec₂₀₀₀) and their coefficients V , V_R , and V_F , respectively.

Table 1 also lists the following data based on all the surveys: mean flux densities \overline{F} of these objects (column 5), absolute σ^{set} and relative RMS^{set} root mean square deviations from the mean values \overline{F} (columns 6 and 7 respectively), the angles dH averaged over all surveys (column 8),⁶ and spectral indices α at 3.94 GHz (column 9). The asterisks (*) in column 10 mark the radio sources that are identified in the records with the highest confidence.

5. ANALYSIS OF THE STATISTICAL PROPERTIES OF THE SOURCES

To confirm the variability of the objects with positive long-term variability indices, we use statistical techniques similar to those employed in [3, 13, 34–36]. We compute the absolute ΔF and relative V_χ variability amplitudes as well as the weighted average flux $\langle F \rangle$ of the source, weighted average root mean square error $\langle \sigma \rangle$, and the χ^2

criterion for the number of degrees of freedom $df = n - 1$, where n is the number of surveys. We perform our computations by the following formulas [34]:

$$\langle F \rangle = \sum_i^n (F_i / \sigma_i^2) / \sum_i^n \sigma_i^{-2}, \quad (6)$$

$$\langle \sigma \rangle = \left(\sum_i^n (1 / \sigma_i^2) \right)^{-0.5}, \quad (7)$$

$$\chi^2 = \sum_i^n (F_i - \langle F \rangle)^2 / \sigma_i^2, \quad (8)$$

$$\Delta F = \left((n - 1)[\chi^2 - (n - 1)] / \sum_i^n (F_i / \sigma_i^2) \right)^{0.5},$$

$$V_\chi = \Delta F / \langle F \rangle. \quad (9)$$

We summarize the results of these computations in Table 2. Columns 2, 3, and 4 list the χ^2 probabilities of source variability. The parameter p_{df} provides a quantitative estimate of the probability that a source whose flux density obeys a χ^2 distribution with $df = n - 1$ degrees of freedom can be considered variable ($p = 1 - \chi^2(n - 1)$). We computed the $df' = df - 1$ degrees of freedom χ^2 probabilities for the sources whose flux densities measured in the 1993 and 1994 surveys agree within the measurement errors. In our computations we treated the averaged flux densities measured in 1993 and 1994 as a single data point, thereby reducing the number of degrees of freedom by one. We list the p_{df-1} values in column 3 of Table 2.

⁶ $dH = \Delta \text{Dec} = \text{Dec}^{\text{ist}} - \text{Dec}^0$, where Dec^0 and Dec^{ist} are the declination of the central section of the survey and that of the source, respectively. The latter varies from survey to survey because of precession.

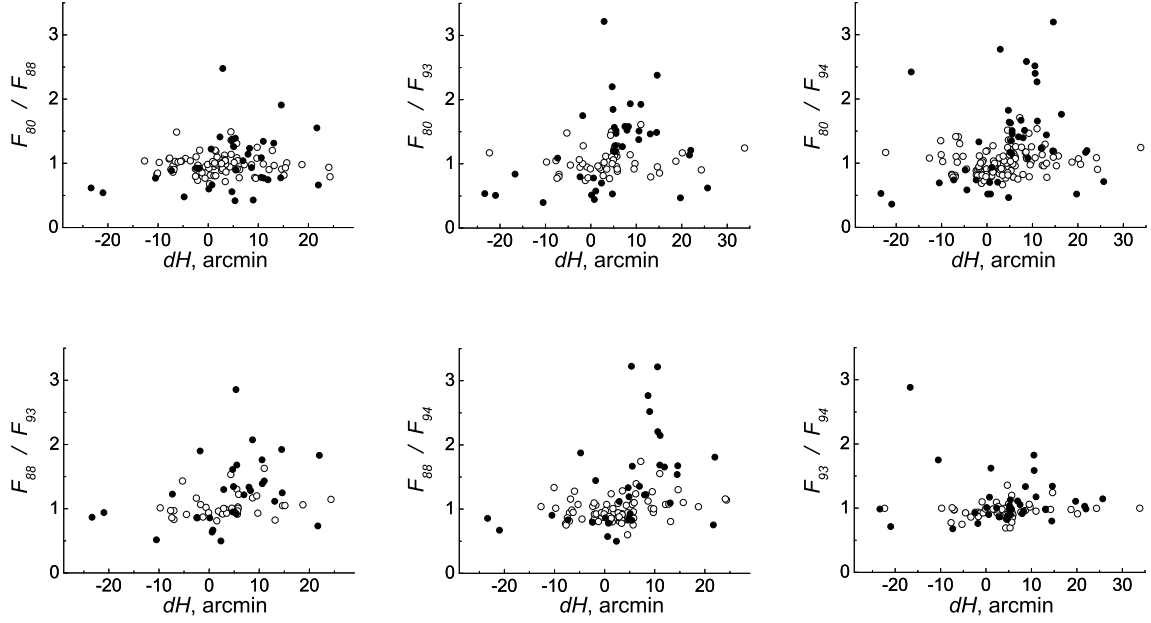


Рис. 2. The F_i/F_j flux density ratios for the studied sample of RCR sources, obtained in different surveys ($i, j = 1980, 1988, 1993$, and 1994). The filled circles show the F_i/F_j ratios for the objects in Table 1 (sources with $V > 0$), and the open circles—for objects with $V \leq 0$.

Column 4 lists the average probabilities $\bar{p} = (p_{df} + p_{df-1})/2$.

Column 5 lists the weighted average flux densities $\langle F \rangle$, column 6 lists their absolute variability amplitudes ΔF , column 7 gives the parameter V_χ , columns 8 and 9 give the absolute $\langle \sigma \rangle$ and relative $\langle \sigma \rangle^{\text{otn}} = \langle \sigma \rangle / \langle F \rangle$ weighted average root mean square errors, column 10 lists the χ^2 values, and column 11 gives the number of degrees of freedom $df = n - 1$.

Figure 2 shows the F_i/F_j flux density ratios for the considered sample of RCR sources obtained in different surveys ($i, j = 1980, 1988, 1993$, and 1994). The filled circles show the F_i/F_j ratios for the objects in Table 1 (sources with $V > 0$), and the open circles—for objects with $V \leq 0$.

The smallest scatter of data points is between the 1993 and 1994 surveys. For the sample of sources

Таблица 1. Parameters of RCR objects with positive long-term
variability indices V

RCR		V	V_R	V_F	\overline{F} ,	σ^{set} ,	RMS^{set}	\overline{dH} ,	α	Notes
RA ₂₀₀₀	Dec ₂₀₀₀				mJy	mJy		arcmin		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	
J 072919.57+044948.7	0.189	2.09	2.61	51	22	0.428	5.5	−0.67		
J 073357.46+045614.1	0.199	1.90	3.99	265	73	0.276	0.6	0.11	*	
J 075314.02+045129.4	0.025	1.35	1.64	183	25	0.138	4.2	−0.34	*	
J 080757.60+043234.6	0.275	2.68	3.12	374	142	0.380	−23.0	−0.30		
J 081218.14+050755.5	0.097	1.92	1.91	118	32	0.266	11.5	−0.75		
J 081626.62+045852.8	0.106	1.67	2.42	53	14	0.272	3.5	−0.88		
J 083148.89+042938.5	0.130	1.89	2.32	949	247	0.261	−25.5	0.04	*	
J 091636.22+044132.0	0.263	2.52	2.90	171	72	0.424	−13.0	−0.84		
J 092355.77+045645.8	0.087	1.85	1.88	20	6	0.305	3.4	0.16		
J 095218.73+050559.3	0.187	2.41	2.15	60	34	0.565	9.9	−0.43		
J 100534.80+045119.8	0.104	1.94	1.79	36	10	0.270	−1.3	−0.56		
J 101603.12+051303.6	0.147	1.81	2.74	574	177	0.309	17.7	0.04	*	
J 103846.84+051229.6	0.050	1.55	1.81	455	79	0.175	20.2	0.24	*	
J 104117.65+045306.4	0.157	2.08	2.61	42	13	0.307	−2.1	−0.82		
J 104527.19+045118.7	0.043	1.75	1.70	32	8	0.246	−1.9	−0.85		
J 105253.05+045735.3	0.039	1.41	1.82	102	16	0.160	3.9	−0.15	*	
J 105719.26+045545.4	0.200	2.20	2.90	30	11	0.350	2.0	−0.02		
J 113156.47+045549.3	0.050	1.39	1.95	250	36	0.145	3.8	−0.84	*	
J 114521.30+045526.7	0.018	1.26	1.62	501	51	0.102	3.5	−0.33	*	
J 114631.64+045818.2	0.056	1.52	1.90	193	37	0.192	4.9	−0.21	*	
J 115248.33+050057.2	0.171	2.22	2.24	49	16	0.332	7.5	−0.89		
J 115336.08+045505.2	0.175	2.15	2.60	35	10	0.300	1.6	0.78		
J 115851.23+045541.9	0.335	3.09	3.91	21	13	0.640	0.6	−0.11		
J 123507.25+045318.7	0.376	3.22	4.63	38	23	0.623	−0.1	−0.05	*	
J 123725.63+045741.6	0.032	1.44	1.67	92	18	0.198	4.1	−1.15	*	

Таблица 1. (Contd.)

RCR RA ₂₀₀₀ Dec ₂₀₀₀	V	V_R	V_F	\overline{F} , mJy	σ^{set} , mJy	RMS ^{set}	\overline{dH} , arcmin	α	Notes
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
J 123932.78+044305.3	0.027	1.47	1.58	291	55	0.191	−10.4	−0.13	*
J 124145.15+045924.5	0.227	2.52	2.53	37	21	0.558	4.2	−0.57	
J 125755.32+045917.6	0.072	1.58	2.02	153	33	0.217	5.3	−1.01	
J 130631.65+050231.3	0.056	1.67	1.67	61	16	0.257	8.8	−0.25	
J 133541.21+050124.9	0.216	2.77	2.11	34	14	0.406	4.1	−0.96	
J 133920.76+050159.3	0.116	2.09	1.79	47	16	0.348	4.6	−0.30	
J 134201.37+050157.5	0.108	1.77	2.08	68	21	0.309	6.1	0.85	
J 135050.06+045148.9	0.173	2.11	2.41	30	10	0.336	−2.0	0.44	
J 141920.56+051110.6	0.104	2.22	1.91	137	48	0.351	17.0	−0.27	
J 142409.47+043451.7	0.231	3.01	2.46	317	148	0.467	−20.0	−0.20	*
J 145032.99+050824.6	0.082	1.76	1.90	121	46	0.377	11.9	−0.32	
J 151141.19+051809.4	0.019	1.40	1.44	395	91	0.230	23.3	1.11	
J 161015.24+044923.5	0.080	1.80	1.90	33	13	0.403	−4.3	−0.20	*
J 161637.49+045932.8	0.067	1.48	2.19	932	217	0.233	3.8	0.22	
J 163106.83+050119.2	0.110	1.67	2.21	79	23	0.299	4.2	−0.90	
J 165643.92+050014.0	0.096	1.63	2.33	53	15	0.288	3.8	−0.73	*

Таблица 2. Statistical properties of RCR objects with positive long-term variability indices V

RCR RA ₂₀₀₀ Dec ₂₀₀₀	pdf	$pdf-1$	\overline{p} ,	$\langle F \rangle$, mJy	ΔF , mJy	V_χ	$\langle \sigma \rangle$, mJy	$\langle \sigma \rangle^{\text{otn}}$	χ^2	df
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
J 072919.57+044948.7	0.966		0.966	42	16	0.385	5	0.124	6.82	2
J 073357.46+045614.1	1	0.999	0.999	266	103	0.388	15	0.056	18.80	3
J 075314.02+045129.4	0.653	0.796	0.725	173	10	0.057	10	0.059	3.31	3

Таблица 2. (Contd.)

RCR RA ₂₀₀₀ Dec ₂₀₀₀	p_{df}	p_{df-1}	\bar{p} ,	$\langle F \rangle$, mJy	ΔF , mJy	V_χ	$\langle \sigma \rangle$, mJy	$\langle \sigma \rangle^{\text{otn}}$	χ^2	df
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
J 080757.60+043234.6	0.991	0.995	0.993	302	179	0.594	37	0.124	10.67	3
J 081218.14+050755.5	0.738	0.906	0.823	110	21	0.194	12	0.112	4.01	3
J 081626.62+045852.8	0.974	0.990	0.983	51	17	0.337	4	0.078	9.25	3
J 083148.89+042938.5	0.960	0.984	0.972	859	316	0.367	79	0.092	8.31	3
J 091636.22+044132.0	0.965		0.965	136	62	0.453	15	0.111	8.55	3
J 092355.77+045645.8	0.810	0.890	0.850	18	5	0.270	2	0.117	3.62	3
J 095218.73+050559.3	0.922	0.976	0.949	45	18	0.403	7	0.161	5.13	3
J 100534.80+045119.8	0.955	0.981	0.968	29	11	0.377	3	0.096	8.12	3
J 101603.12+051303.6	0.966	0.987	0.976	536	179	0.334	43	0.081	8.67	3
J 103846.84+051229.6	0.703	0.839	0.771	442	54	0.121	37	0.084	3.70	3
J 104117.65+045306.4	0.982	0.994	0.989	35	14	0.414	3	0.087	10.56	3
J 104527.19+045118.7	0.673	0.808	0.741	28	6	0.202	3	0.105	4.37	3
J 105253.05+045735.3	0.808	0.895	0.852	101	15	0.149	7	0.065	4.74	3
J 105719.26+045545.4	0.978	0.990	0.984	28	12	0.427	3	0.108	10.42	3
J 113156.47+045549.3	0.738	0.842	0.790	239	26	0.110	15	0.064	4.01	3
J 114521.30+045526.7	0.548	0.729	0.639	487	30	0.061	27	0.055	2.63	3
J 114631.64+045818.2	0.854	0.924	0.889	190	31	0.165	12	0.062	5.36	3
J 115248.33+050057.2	0.974		0.974	39	20	0.513	5	0.119	9.23	3
J 115336.08+045505.2	0.974	0.989	0.981	33	13	0.393	3	0.083	9.59	3
J 115851.23+045541.9	0.999	1	0.999	19	17	0.882	2	0.128	18.87	3
J 123507.25+045318.7	1	1	1	33	25	0.753	3	0.093	25.06	3
J 123725.63+045741.6	0.680	0.828	0.754	88	8	0.089	6	0.072	3.51	3
J 123932.78+044305.3	0.844		0.840	281	40	0.135	19	0.069	3.70	3
J 124145.15+045924.5	0.961		0.961	29	14	0.491	5	0.163	6.54	2
J 125755.32+045917.6	0.868	0.939	0.904	148	27	0.184	10	0.066	5.59	3
J 130631.65+050231.3	0.764		0.764	54	9	0.159	6	0.119	2.89	2

Таблица 2. (Contd.)

RCR RA ₂₀₀₀ Dec ₂₀₀₀	p_{df}	p_{df-1}	\bar{p} ,	$\langle F \rangle$, mJy	ΔF , mJy	V_χ	$\langle \sigma \rangle$, mJy	$\langle \sigma \rangle^{\text{otn}}$	χ^2	df
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
J 133541.21+050124.9	0.902	0.933	0.764	25	13	0.519	4	0.165	6.30	3
J 133920.76+050159.3	0.871		0.917	36	11	0.307	5	0.149	4.13	2
J 134201.37+050157.5	0.857	0.931	0.871	60	17	0.279	6	0.103	5.45	3
J 135050.06+045148.9	0.972	0.989	0.894	23	11	0.481	3	0.113	9.03	3
J 141920.56+051110.6	0.845	0.943	0.980	131	27	0.203	22	0.167	3.72	2
J 142409.47+043451.7	0.988		0.988	296	143	0.484	39	0.131	8.82	2
J 145032.99+050824.6	0.925		0.925	111	25	0.235	18	0.164	3.61	1
J 151141.19+051809.4	0.725	0.876	0.801	366	49	0.133	44	0.122	2.59	2
J 161015.24+044923.5	0.919		0.919	31	7	0.223	5	0.159	3.07	1
J 161637.49+045932.8	0.948	0.984	0.967	920	198	0.214	71	0.077	5.92	2
J 163106.83+050119.2	0.920	0.972	0.947	72	17	0.241	7	0.097	5.09	2
J 165643.92+050014.0	0.954	0.988	0.971	51	14	0.269	5	0.093	6.18	2

with $V \leq 0$ the standard deviations of determination or are close to it, suggesting flux density ratios from the corresponding that the sources of our sample are variable mean ratio are equal to 0.11, 0.15, 0.20, 0.19, mostly on time scales of 6–8 years. The 0.18, and 0.19, for F_{94}/F_{93} , F_{80}/F_{88} , F_{80}/F_{93} , exceptions are objects J 091636+044132, F_{80}/F_{94} , F_{88}/F_{93} , and F_{88}/F_{94} , respectively. J 115248+050057, J 123932+044305, and The standard deviations for the sample of J 142409+043451.

possibly variable objects ($V > 0$) are equal to 0.40, 0.44, 0.63, 0.70, 0.53, and 0.72, for F_{94}/F_{93} , F_{80}/F_{88} , F_{80}/F_{93} , F_{80}/F_{94} , F_{88}/F_{93} , and F_{88}/F_{94} , respectively.

The differences of flux density ratios in the 1993 and 1994 surveys for most of the possibly variable objects from Table 1 do not exceed the standard error of flux

It follows from a comparison of the data listed in Tables 1 and 2 that the weighted average flux density ratios $\langle F \rangle$ computed by formula (6) practically coincide with \bar{F} within the errors. Also close are the σ^{set} (Table 1) and ΔF (Table 2) values for individual sources, and V_χ and $\text{RMS}^{\text{set}} = \sigma^{\text{set}}/\bar{F}$.

For the sources listed in Tables 1 and 2

the relative variability amplitudes V_χ and relative standard deviations from the mean, RMS^{set} , mostly exceed substantially the corresponding relative weighted standard errors of the measured flux densities $\langle\sigma\rangle^{\text{otn}}$. This is evident from Fig. 3, which shows how the above quantities depend on angle dH : $\langle\sigma\rangle^{\text{otn}}$ (the filled circles) and V_χ (the open triangles). The relative standard deviations $\overline{\text{RMS}}^{\text{set}}$ and \overline{V}_χ averaged over all sources with $V > 0$ are equal to 0.315 ± 0.125 and 0.317 ± 0.182 respectively, and $\overline{\langle\sigma\rangle^{\text{otn}}} = 0.105 \pm 0.0332$.

Let us now compare the RMS^{set} values for sources with positive and negative long-term variability indices. The upper and lower panels in Fig. 4 show the dependences of RMS^{set} on dH for sources with $V > 0$ and

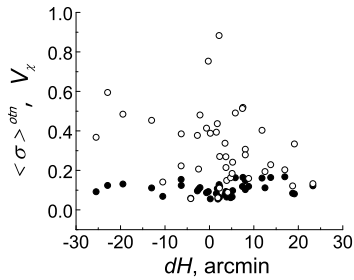


Fig. 3. Dependence of the relative variability amplitude V_χ and relative weighted average standard error of the measured flux densities $\langle\sigma\rangle^{\text{otn}}$ on angle dH for sources with $V > 0$. The open and filled circles show the dependences for V_χ and $\langle\sigma\rangle^{\text{otn}}$ respectively.

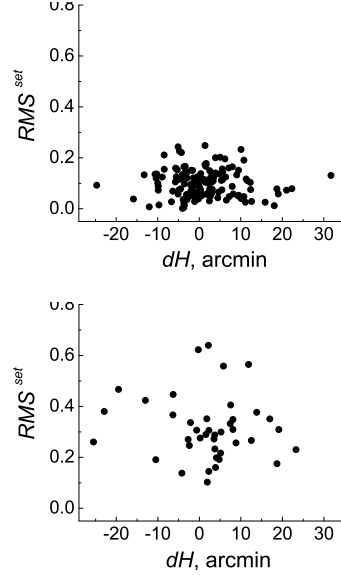


Fig. 4. Relative standard deviation RMS^{set} from the mean value averaged over all surveys as a function of angle dH for sources with $V > 0$ (the upper panel) and $V \leq 0$ (the lower panel).

$V \leq 0$ respectively. The RMS^{set} values for possibly variable objects ($V > 0$) exceed significantly the RMS^{set} for objects with $V \leq 0$. The same is true for the relative variability amplitudes V_χ of variable and nonvariable sources. The mean $\overline{\text{RMS}}^{\text{set}}$ value averaged over all nonvariable sources ($V \leq 0$) is 0.101 ± 0.062 which is comparable with the averaged $\overline{\langle\sigma\rangle^{\text{otn}}}$ value.

Let us now consider the distribution of right ascensions, declinations (offsets relative to the central section of the survey), flux densities, and spectral indices of the objects with positive long-term variability indices.

The upper and lower panels in Fig. 5 show

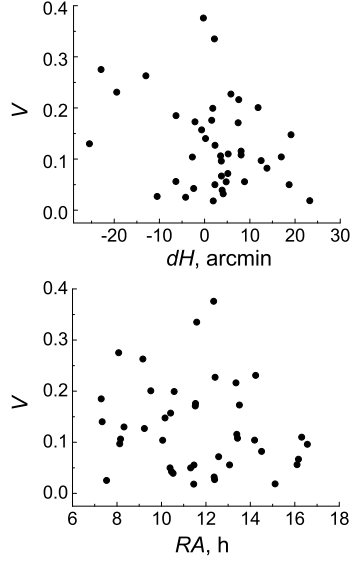


Рис. 5. The long-term variability indices V for objects from Table 1 as a function of angle dH (the upper panel) and RA (the lower panel).

the parameter V plotted as a function of angle dH and RA respectively. Although the sources are distributed sufficiently uniformly in the interval of angles considered, there is a trend for the increase of the number of sources toward the central cross section of the survey which can be explained by the fact that fainter objects can be detected in the vicinity of the central cross section. Variable sources are distributed uniformly in right ascension.

Figure 6 shows the histograms of the distribution of flux densities F (the left panel) and spectral indices α (the central panel) for the sample of possibly variable objects. The right panel shows the histogram

of the distribution of spectral indices for nonvariable sources (with $V < 0$). Almost half of the sources with positive long-term variability indices are bright objects with flux densities above 100 mJy, about one third of the sources have flux densities $F \leq 40$ mJy. The median spectral index of this sample is equal to -0.3 . The distribution exhibits two conspicuous maxima: at $\alpha = -0.75$ and $\alpha = -0.15$.

The median spectral index of nonvariable sources is equal to -0.65 . This subsample is dominated by objects with negative spectral indices.

The upper and lower panels of Fig. 7 show the dependence of the long-term variability index on the signal-to-noise ratio T_a/σ_s and source flux density F respectively. We computed the coefficients V using the antenna temperatures determined in two surveys, and therefore each V value has two corresponding T_a/σ_s ratios, which are shown in Fig. 7 by the filled and open circles respectively. Noteworthy is the fact that the sources with long-term variability indices in the $0 < V < 0.18$ interval have signal-to-noise ratios T_a/σ_s ranging from 3 to 200, whereas the T_a/σ_s ratios for objects with $V > 0.18$ do not exceed 20. Note that only three sources have antenna temperatures at $3\sigma_s$ in one of the surveys, whereas the remaining sources have $T_a \geq 5\sigma_s$.

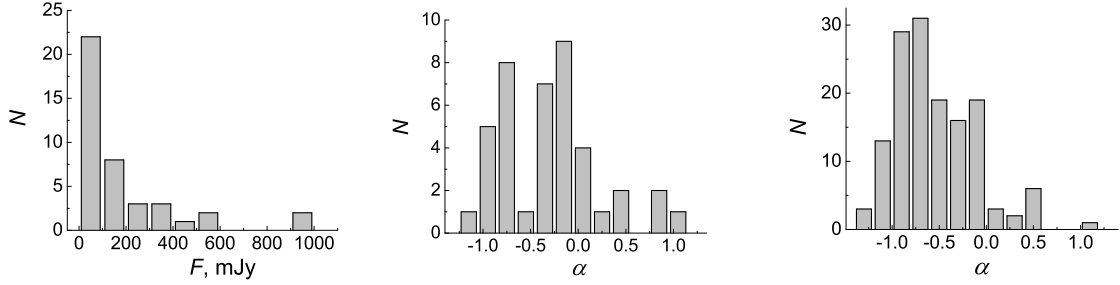


Рис. 6. Histograms of the flux densities F (the left panel) and spectral indices α (the central panel) of possibly variable objects (with $V > 0$) from Table 1. The right panel shows the histogram of the spectral indices of nonvariable sources (with $V < 0$).

6. VARIABLE SOURCES OF THE RCR CATALOG

Let us now discuss the criteria that allow the objects with $V > 0$, listed in Tables 1 and 2, to be considered variable. Kesteven, Bridle, and Brandie [35], and Fanti et al. [36] considered a source to be possibly and reliably variable if its χ^2 probability satisfied the condition $0.1\% \leq 1 - p \leq 1\%$ ($0.99 \leq p < 0.999$) and $1 - p \leq 0.1\%$ ($p \geq 0.999$) respectively.

Seielstad, Pearson, and Readhead [34], and Gorshkov and Konnikova [3] considered the objects with $p \geq 0.985$ and $p \geq 0.98$ to be reliably variable, and those with $0.95 \leq p < 0.98$ possibly variable.

Three sources (J073357+045614, J115851+045541, J123507+045318) out of 41 objects listed in Tables 1 and 2 satisfy the condition

$p \geq 0.999$.⁷ Twelve and six sources have χ^2 probabilities in the $0.98 < p < 0.999$ and $0.95 < p < 0.98$ intervals respectively. So, 15 sources can be considered to be reliably variable in accordance with the criteria proposed in [3, 34–36], and six sources can be considered to be possibly variable. Another six sources have $0.90 \leq p < 0.95$.

These results are mostly based on the p_{df-1} values computed using the averaged flux densities measured in the 1993 and 1994 surveys. For the objects with the 1993 and 1994 survey flux density differences exceeding the measurement errors of F , we use the p_{df} probabilities. Thus, the source variability found in this study has a typical time scale of 6–8 years.

⁷ The source J073357+045614 satisfies this condition if the flux density measured during the 1993 set is taken into account. Without the 1993 set the χ^2 probability for this object is $p = 0.966$.

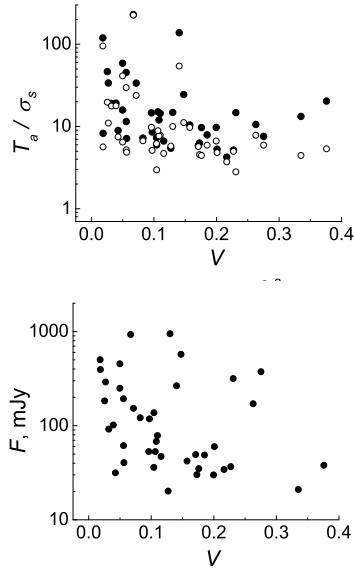


Fig. 7. Dependence of the long-term variability indices V of the sources from Table 1 on the signal-to-noise ratio (T_a/σ_s) (the upper panel) and flux density F (the lower panel).

If we base our analysis on the average probabilities \bar{p} listed in Table 2, the same three sources satisfy the condition $p \geq 0.999$, seven sources satisfy the condition $0.98 < p < 0.999$, and 11 sources satisfy the condition $0.947 \leq p < 0.98$. That is, the total number of reliably variable and possibly variable objects (21 sources) remains the same, and only the proportion changes. All these radio sources, except one, have long-term variability indices $V \gtrsim 0.1$.

Ting et al. [33] used the coefficient V_F as the variability criterion. They considered a source to be variable if its parameter

V_F was greater than or equal to 3. For such objects the difference between the flux densities measured in different surveys exceeds 3σ (formula (2)). Out of the 21 most likely variable sources ($0.95 < p \leq 0.999$), four meet this criterion, two more have $V_F \geq 2.9$, and all the remaining sources, except one, have $2.1 < V_F < 2.9$.

Consider now the use of the relative variability amplitude V_χ as a criterion. An analysis of the data reported by Seielstad, Pearson, and Readhead [34] showed that for most of the sources with $p \geq 0.985$ this parameter is no less than 0.2. Among the 21 sources claiming to be variable with the probability $p > 0.95$, 18 objects have $V_\chi > 0.3$, and three have relative variability amplitudes in the interval $0.2 < V_\chi < 0.3$. The latter three sources pass rather close to the central cross section of the survey, and their long-term variability indices are equal to 0.067, 0.096, and 0.11.

And now a few words about the parameter V_R , which characterizes the maximum to minimum flux density ratio for a particular source measured in different surveys. All the most likely variable objects have $V_R \gtrsim 1.5$.

Note that the variability criteria V , V_χ , V_F , and V_R , considered here, are interrelated. Figure 8 shows, as an example, the dependences of the long-term variability indices V of the sources from Table 1 on

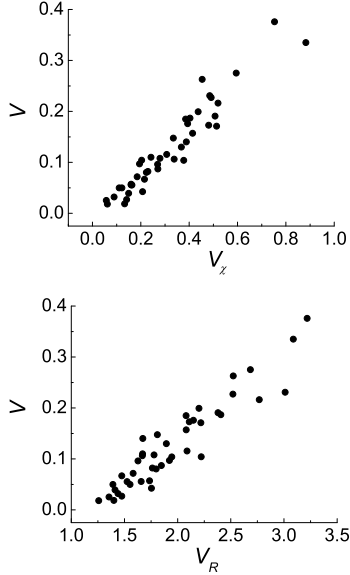


Рис. 8. Dependence of the long-term variability index V of the sources from Table 1 on variability amplitude V_x (the upper panel) and parameter V_R (the lower panel).

variability amplitude V_x (the upper panel) and parameter V_R (the lower panel).

An analysis of the obtained results suggests that all the sources listed in Tables 1 and 2 (a total of 41 objects) can be suspected of variability, because the differences of their flux densities measured in different surveys exceed the total flux measurement errors. However, the reliability of this conclusion (i.e., that the object is variable) is different for different sources. Among the 41 sources, 15 are reliably variable with the probabilities $p > 0.98$, and three are variable with a probability of $p \geq 0.999$. Six sources with probabilities in the $0.95 < p < 0.98$ interval

are possibly variable in accordance with the criteria proposed in [3, 34]. The variability probabilities for the remaining 20 objects from Table 1 lie in the $0.73 \leq p < 0.95$ interval.

Among the 21 sources with $p > 0.95$, one third have flux densities above 150 mJy, seven have flux densities in the $40 < \overline{F} < 100$ mJy interval, and seven objects have flux densities in the $20 < \overline{F} < 40$ mJy interval. Most of these sources are objects with nearly flat spectra, and two have inverted spectra. One third of the sources have spectral indices $\alpha < -0.67$.

Figure 9 shows the light curves (the left panel) and spectra (the right panel) for the sources with $V > 0$. Figure 10 shows, as an example, the light curves and spectra of the variable flat-spectrum radio sources J155035+052710 and J165833+051516, which have long-term variability indices $V < 0$, according to the data of our surveys. The parameter V for J165833+051516 becomes positive if we set the relative standard error of flux density measurement equal to the averaged value $\overline{\text{RMS}}^{\text{set}} = 0.10$ obtained from the sample of objects with $V \leq 0$.

In conclusion, we summarize the main results of our search for variable sources reported in this and our earlier paper [13]. Out of the total number of sources (about

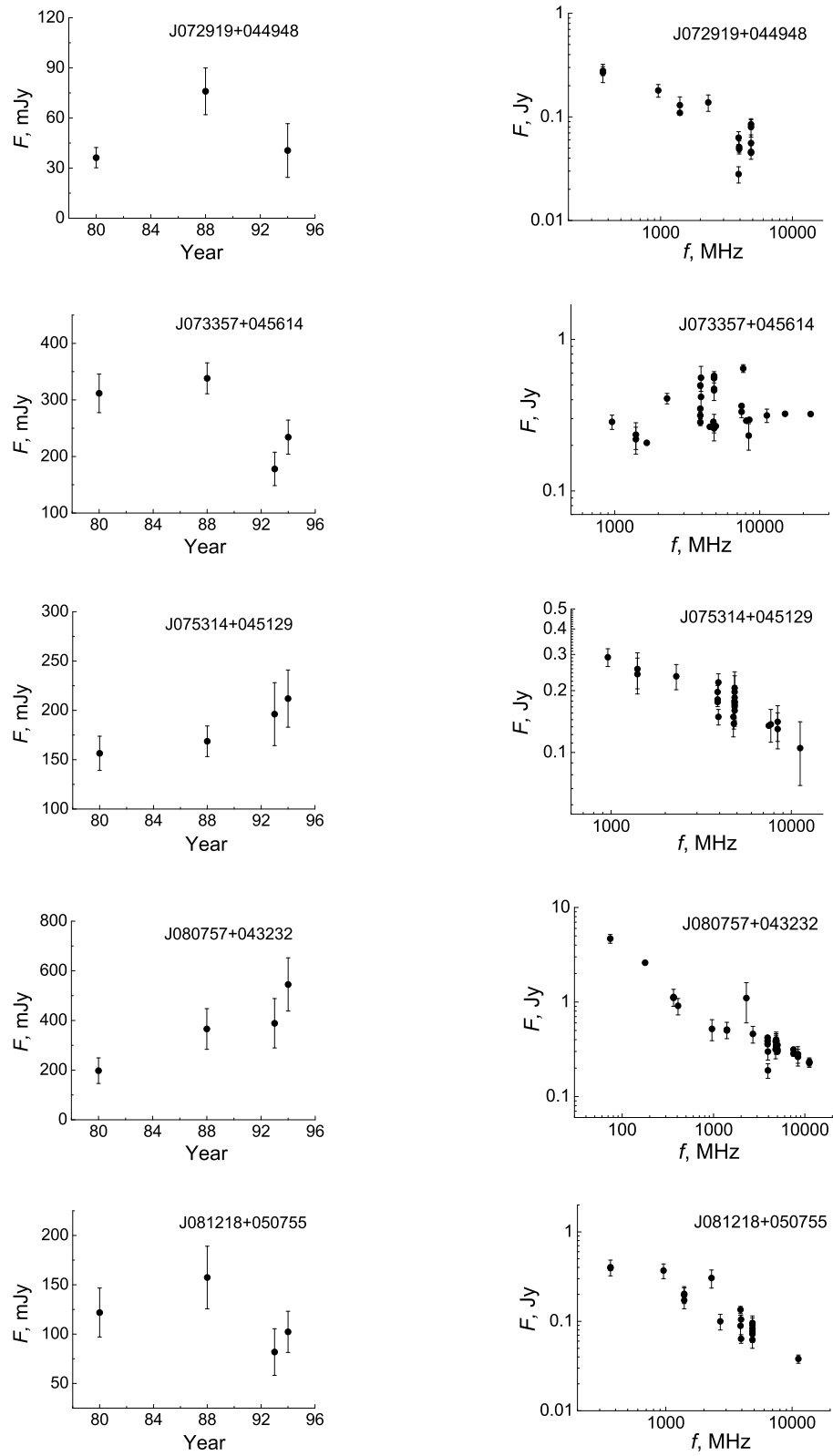


Рис. 9. Light curves (the left panel) and spectra (the right panel) of radio sources with $V > 0$.

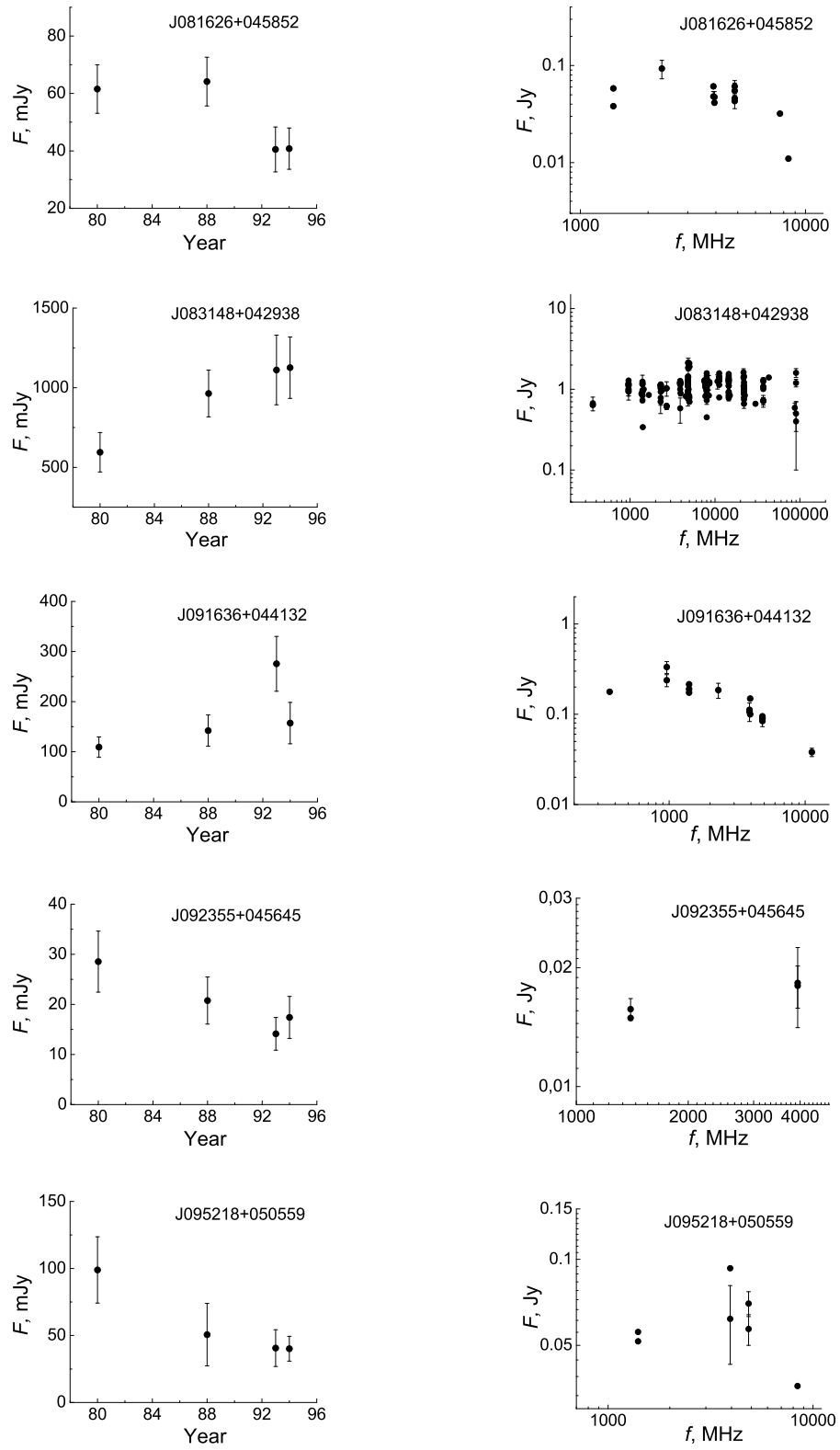


Рис. 9. (Contd.)

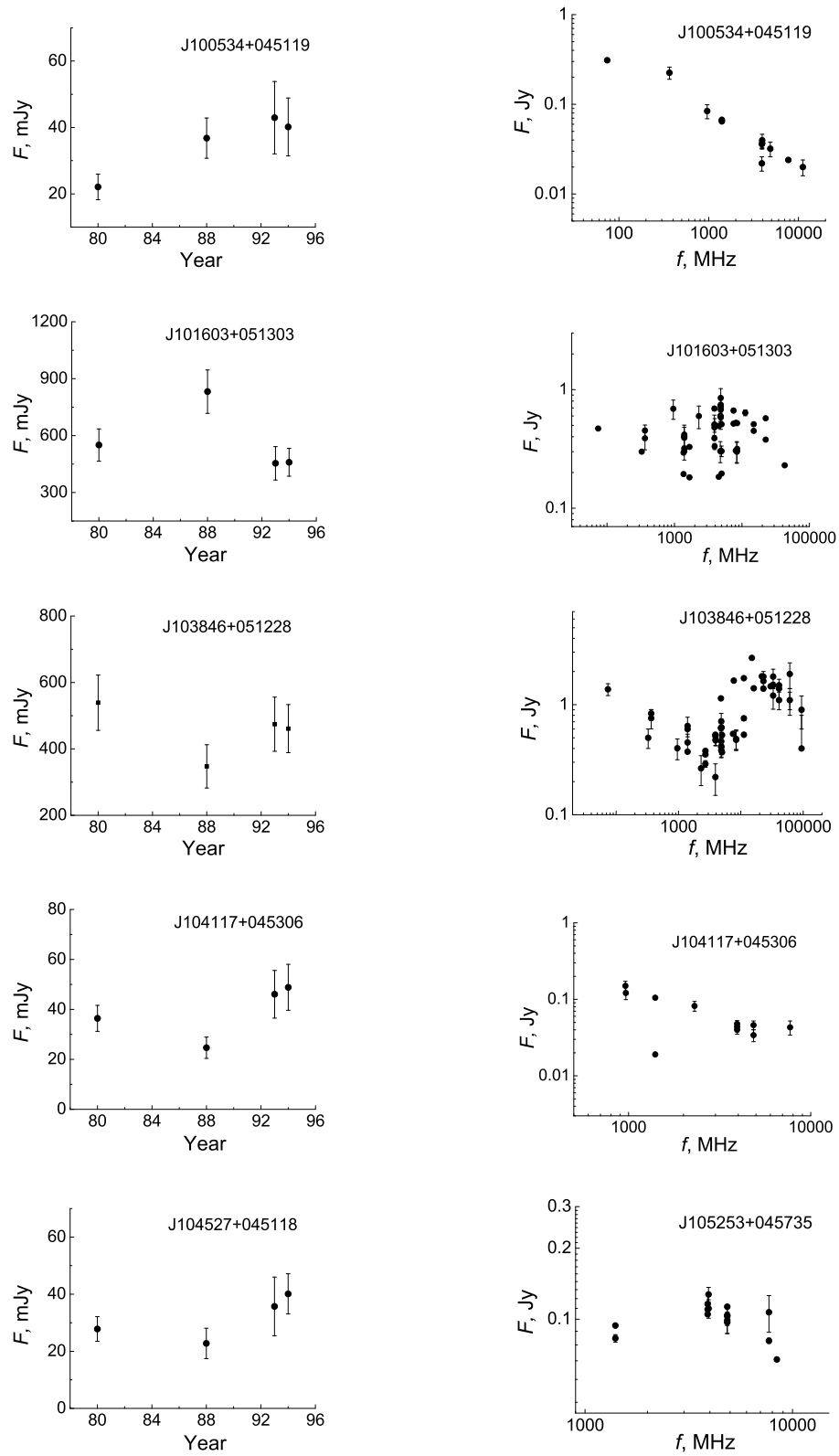


Рис. 9. (Contd.)

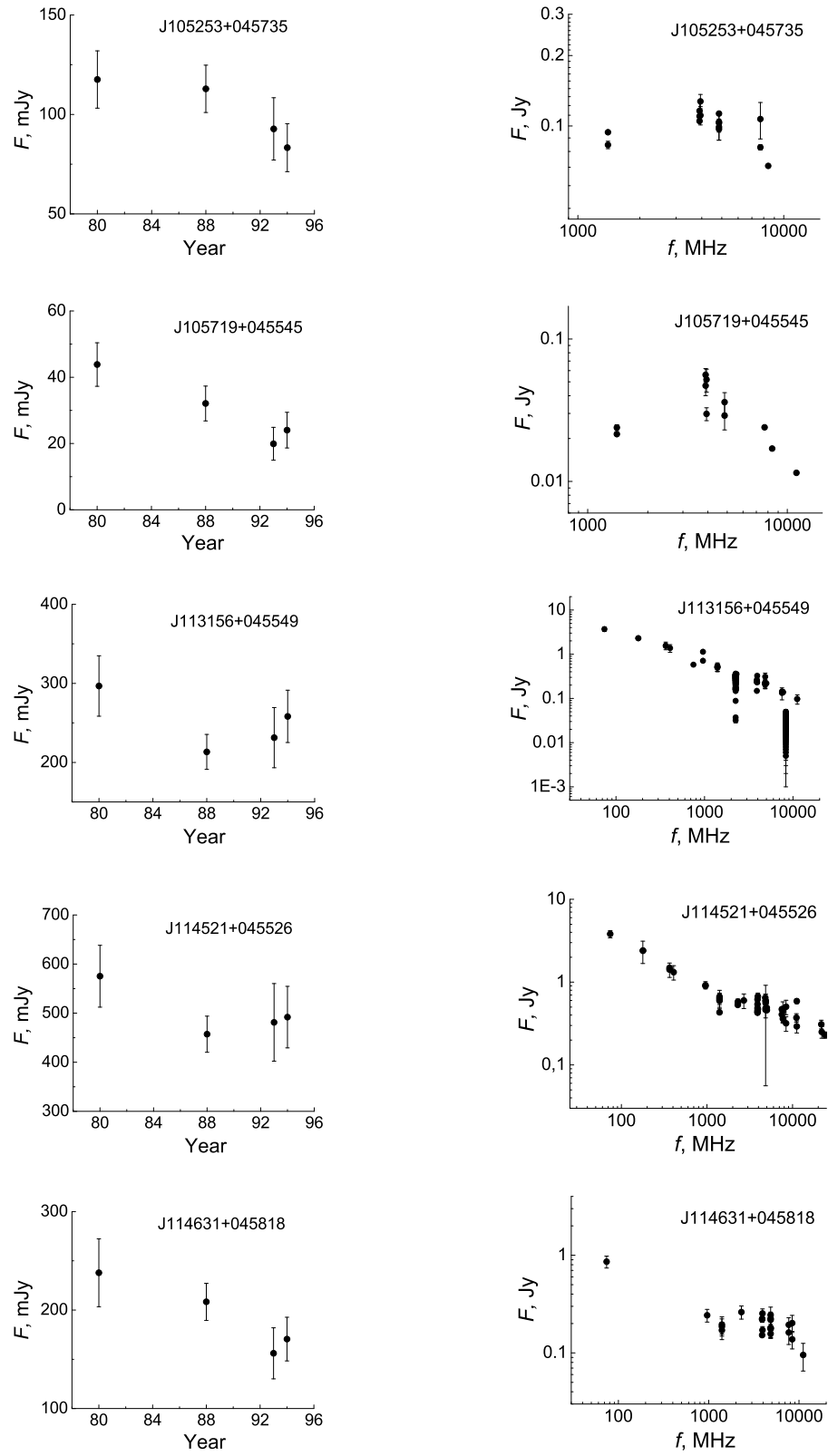


Рис. 9. (Contd.)

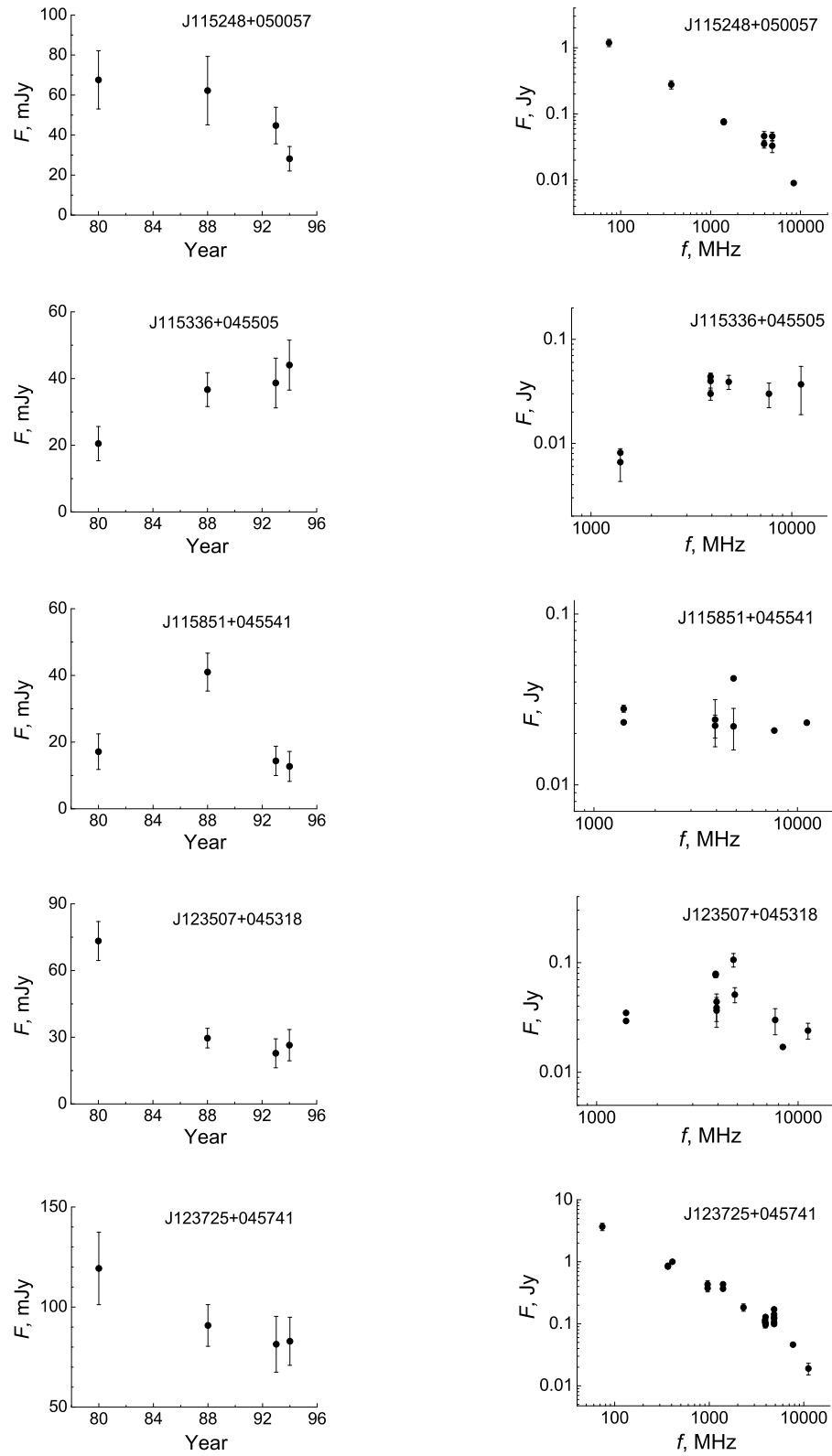


Рис. 9. (Contd.)

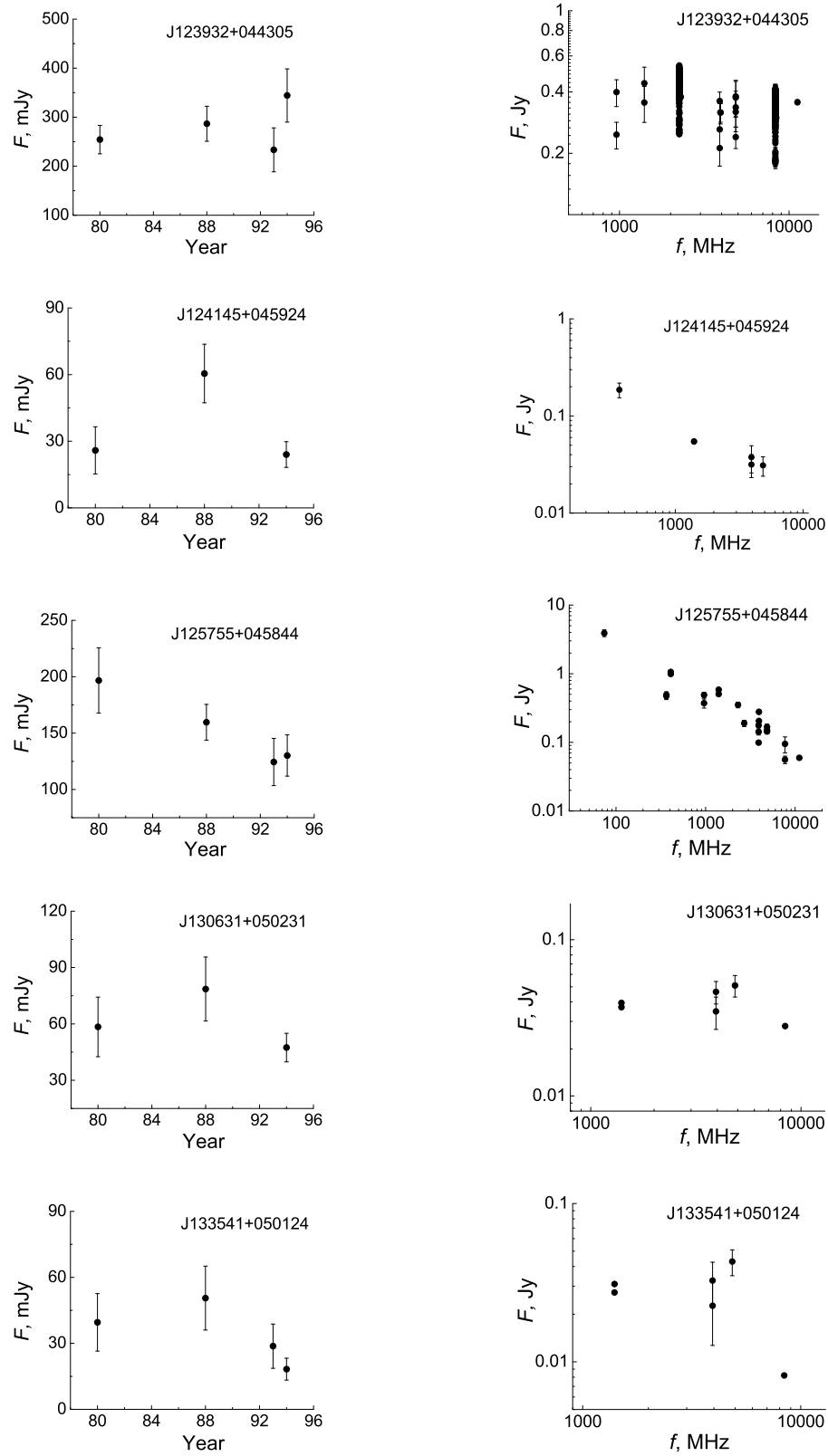


Рис. 9. (Contd.)

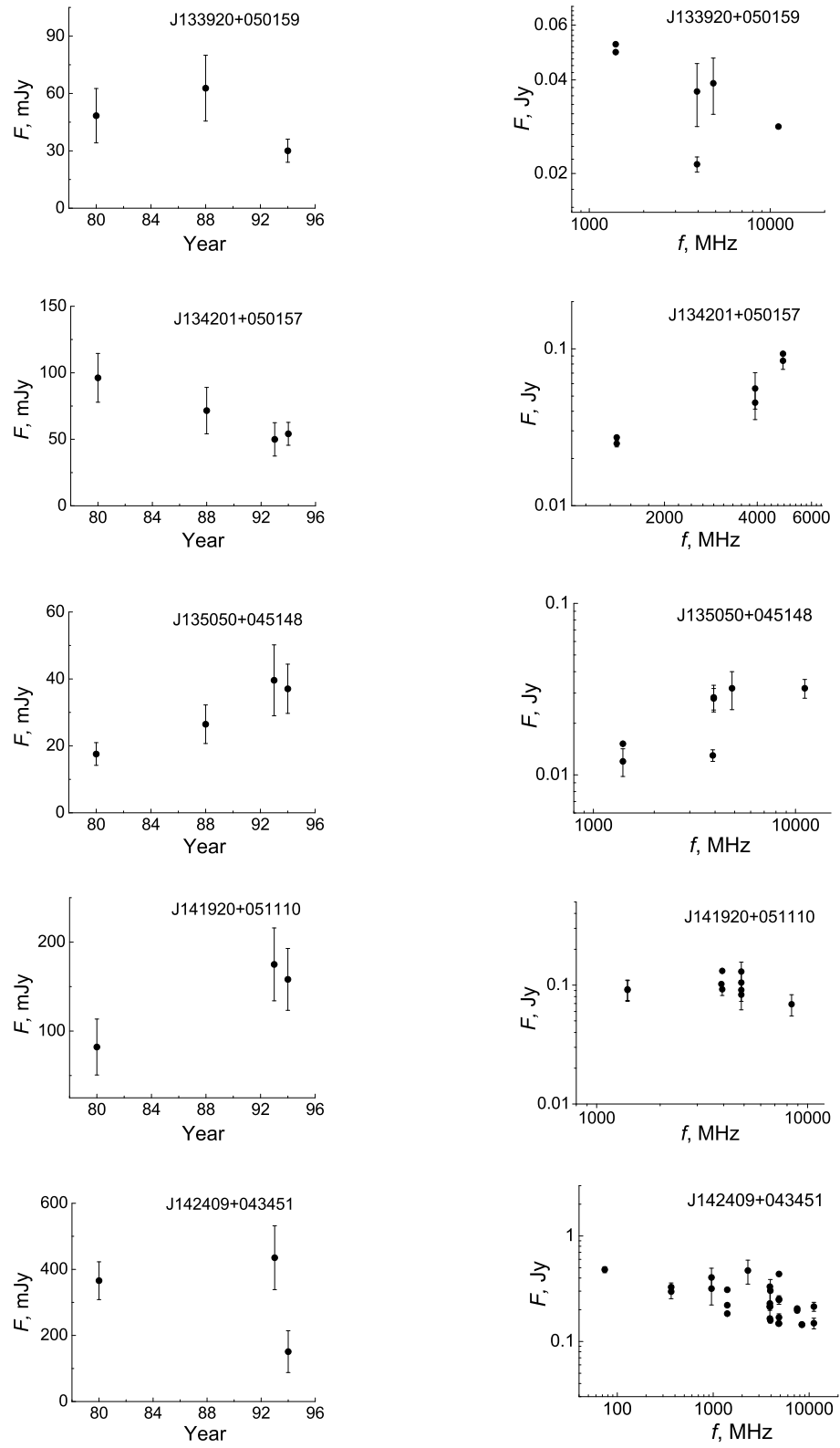


Рис. 9. (Contd.)

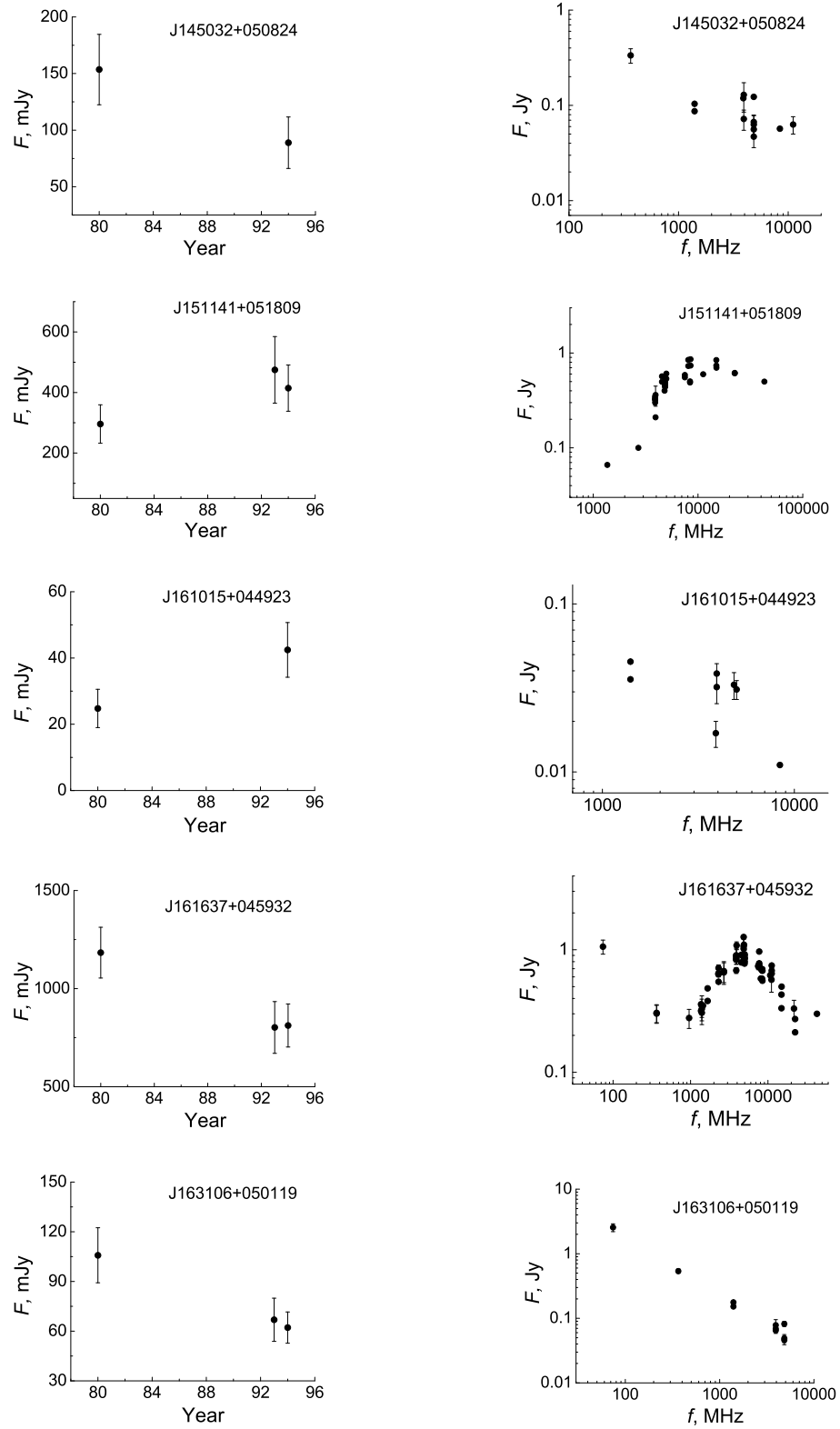


Рис. 9. (Contd.)

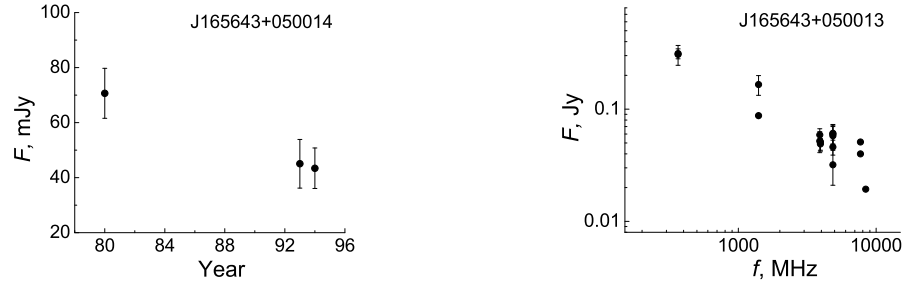


Рис. 9. (Contd.)

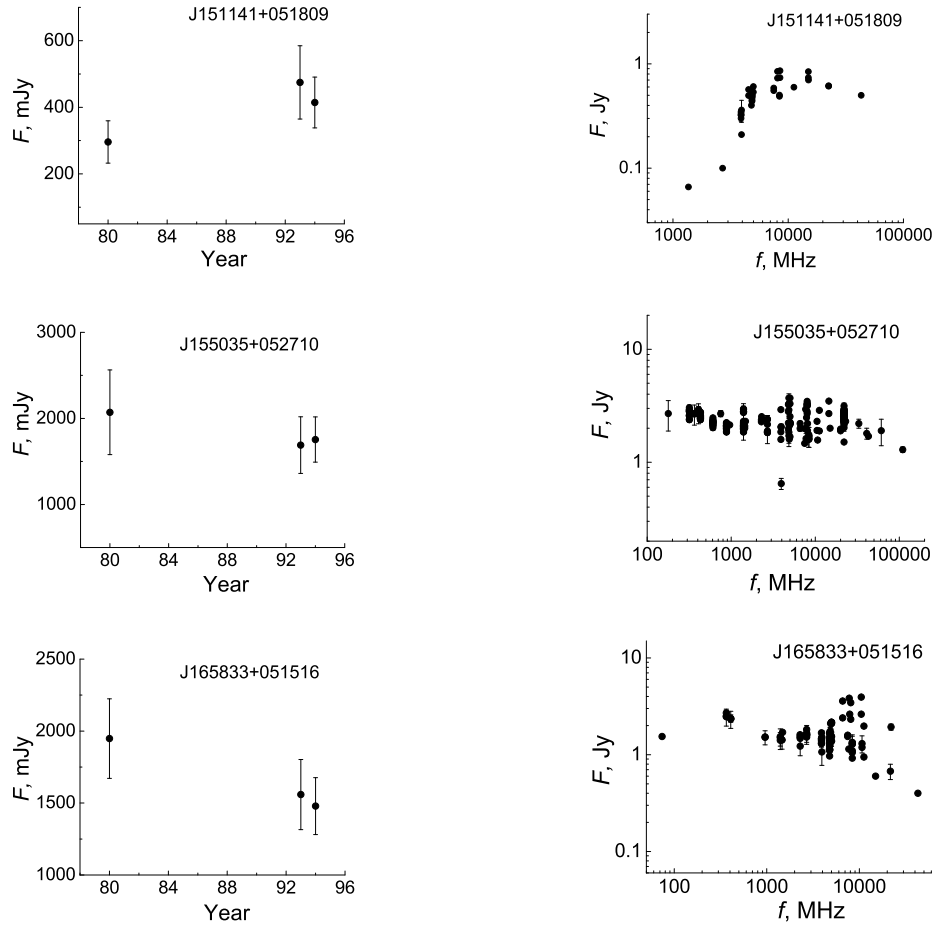


Рис. 10. Light curves (the left panel) and spectra (the right panel) of variable radio sources with flat spectra whose long-term variability indices are negative, $V < 0$, according to the data of our surveys.

280) studied in these papers, 55 proved to have positive long-term variability indices for at least one pair of surveys. We list these sources (with $V > 0$) in Table 3. It includes objects from Tables 1 and 2 of this paper and Tables 3 and 4 from [13].

Among the 55 radio sources listed in Table 3, 15 and 9 objects meet the condition of reliable ($p > 0.98$) and possible ($0.95 < p < 0.98$) variability, respectively. Thirty-five out of 55 objects have relative variability amplitudes $V_\chi > 0.2$, and only six have $V_\chi < 0.1$.

Column 1 gives the coordinates (RA₂₀₀₀, Dec₂₀₀₀) of the objects, columns 2 and 3 give the long-term variability index V and maximum χ^2 probability p , and column 4 gives the relative variability amplitude V_χ . Column 5 gives the type of the host galaxy of the object in the optical range (Type_{opt}): QSO, qso—a quasar (lowercase letters indicate that the type of the object was determined from photometric data); BLLac—BL Lacertae type object; G, g—a galaxy, and Sy—a Seyfert galaxy. Column 6 gives the redshift Z , and the “+” sign in column 7 indicates the spectroscopic redshift. Column 8 gives the spectral index (α), and column 9 gives the morphology (Mrph) of the radio source. The uppercase letters denote the classification based on FIRST maps, and the lowercase letters represent

the classification based on NVSS maps: C or c indicate a point source (Core); D or d—a double source (Double)⁸; CL—a core with components (Core-Lobe)⁹; CJ—a core with a jet (Core-Jet), and T—a triple source (Triple). Column 10 gives the type of the radio source (Type_r): FSRQ—a flat spectrum radio quasar; FSRs—a flat spectrum radio source; GPS, MPS—a Gigahertz or Megahertz peaked source, and FRI, FRII—the Fanaroff and Riley class I or II objects [37]. The letters “o” and “r” in column 11 indicate objects that are variable or possibly variable (“?”) in the optical range and at radio frequencies respectively. The “#” symbol

⁸ DC is a double source with a core (Double-Core), and DD is a doubled double structure (Double-Double). The “w” symbol refers to the “winged” or “X-shaped” morphology.

⁹ The extra symbol “S” indicates “S-shaped” sources.

Таблица 3. Full list of RCR objects with $V > 0$ obtained in this study and in our previous paper [13] and the properties of these objects

RCR RA ₂₀₀₀ Dec ₂₀₀₀	V	p	V_χ	Type _{opt}	Z	l_Z	α	Mrph	Type _r	Var	Notes
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
J 072919.57+044948.7	0.189	0.966	0.385	g			−0.67	c			
J 073357.46+045614.1	0.199	0.999	0.388	QSO	3.010	+	0.12	C	FSRQ	o?	
J 074239.65+050704.3	0.077	0.855	0.180	Sy2	0.160	+	−0.85	d?	FR II?	o	#
J 075314.02+045129.4	0.025	0.796	0.057	G	0.450		−0.35	C	FSRS		
J 080757.60+043234.6	0.275	0.995	0.594	QSO	2.877	+	−0.30	C	FSRQ	o	
J 081218.14+050755.5	0.097	0.906	0.194	qso			−0.75	C			
J 081626.62+045852.8	0.106	0.990	0.337	G	0.080		−0.61	CL, S	GPS?	o	
J 083148.89+042938.5	0.130	0.984	0.367	BL Lac	0.174	+	0.04	CJ	FSRS	o, r	
J 091636.22+044132.0	0.263	0.965	0.453	G	0.184	+	−0.84	T	MPS?	o	
J 095218.73+050559.3	0.201	0.976	0.403	QSO	0.400		0.27	C		o	
J 100534.80+045119.8	0.104	0.981	0.377	g			−0.56	D?	FR II?		
J 101515.33+045305.6	0.061	0.864	0.168	g			−1.04	C			#
J 101603.12+051303.6	0.147	0.987	0.334	QSO	1.702	+	0.04	C	FSRQ	r	
J 103846.84+051229.6	0.050	0.839	0.121	QSO	0.473	+	0.24	T	FSRQ	o?	
J 103938.62+051031.1	0.264	0.984	0.480	G	0.068	+	−0.74	D, w	FR II	o	#
J 104117.65+045306.4	0.157	0.994	0.414	G	0.068	+	−0.82	T?		o	
J 104527.19+045118.7	0.043	0.808	0.202	g			−0.85	C			
J 104551.72+045553.9	0.035	0.691	0.083	g			−0.99	D?			#
J 105253.05+045735.3	0.039	0.895	0.149	g			−0.28	D?	GPS?		
J 105719.26+045545.4	0.200	0.990	0.427	QSO	1.334	+	−0.20	C	GPS?	o?	
J 110246.51+045916.7	0.082	0.925	0.228	G	0.630		−0.81	D, w	FR II		#
J 112437.45+045618.8	0.057	0.895	0.164	Sy2	0.283	+	−0.87	D	FR II	o?	#
J 113156.47+045549.3	0.050	0.842	0.110	G	0.844	+	−0.77	C		r	
J 114521.30+045526.7	0.018	0.729	0.061	QSO	1.339	+	−0.33	D	FSRQ	o?	

Таблица 3. (Contd.)

RCR RA ₂₀₀₀ Dec ₂₀₀₀	V	p	V_{χ}	Type _{opt}	Z	l_Z	α	Mrph	Type _r	Var	Notes
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
J 114631.64+045818.2	0.056	0.924	0.165	QSO			−0.21	C?	GPS?		
J 115248.33+050057.2	0.171	0.974	0.513	qso			−0.89	D?			
J 115336.08+045505.2	0.175	0.989	0.393	G	0.313	+	0.78	C	GPS?		
J 115851.23+045541.9	0.335	1.0	0.882	QSO			−0.11	C	FSRQ?	o?	
J 121328.89+050009.9	0.076	0.772	0.176	G	0.700		−1.08	DC	FRII		#
J 121852.16+051449.4	0.007	0.681	0.175	G	0.075	+	−0.67	D		o	#
J 123507.25+045318.7	0.376	1.0	0.753	g?			−0.06	C	GPS?		
J 123723.63+045741.6	0.032	0.828	0.089	g			−1.16	C			
J 123932.78+044305.3	0.027	0.844	0.135	QSO	1.762	+	−0.13	C	FSRQ	o, r	
J 124145.15+045924.5	0.224	0.961	0.491	G			−0.56	D			
J 125755.32+045917.6	0.072	0.939	0.184	G	0.240		−1.01	DD	FRII	o?	
J 130631.65+050231.3	0.056	0.764	0.159	qso			−0.25	C			
J 132448.14+045758.8	0.088	0.762	0.165	qso			−1.03	D	FRII		#
J 133541.21+050124.9	0.216	0.933	0.519	G	0.770	+	−0.04	C			
J 133920.76+050159.3	0.116	0.871	0.307	QSO	1.358	+	−0.27	C		o	
J 134201.37+050157.5	0.108	0.931	0.279	QSO	3.166	+	0.85	C		o	
J 134243.57+050431.5	0.008	0.601	0.026	Sy1	0.136	+	−0.65	CL, S	FRI	o	#
J 135050.06+045148.9	0.173	0.989	0.481	QSO	1.800		0.44	C	GPS?	o	
J 135137.56+043542.0	0.084	0.960	0.294	g			−0.89	C			#
J 140730.77+044934.9	0.007	0.675	0.071	QSO	1.756	+	−0.75	D?		o?	#
J 141920.56+051110.6	0.104	0.943	0.203	QSO	0.787	+	−0.27	C	GPS?	o?	
J 142104.21+050845.0	0.092	0.928	0.280	G	0.455	+	−0.69	C		o?	#
J 142409.47+043451.7	0.231	0.988	0.484	BL Lac	0.665	+	−0.20	CJ	FSRS	o, r	
J 145032.99+050824.6	0.082	0.925	0.235	QSO	1.635	+	−0.32	D	FRII		
J 151141.19+051809.4	0.019	0.725	0.133	Sy1	0.084	+	1.11	C	FRSQ	o	
J 155148.09+045930.5	0.125	0.961	0.275	G			−1.17	D	FRII		#

Таблица 3. (Contd.)

RCR		V	p	V_χ	Type _{opt}	Z	l_Z	α	Mrph	Type _r	Var	Notes
RA ₂₀₀₀	Dec ₂₀₀₀											
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
J 161015.24+044923.5		0.080	0.919	0.223	qso			−0.20	CJ		o, r	
J 161637.49+045932.8		0.067	0.984	0.214	QSO	3.217	+	0.22	C	GPS		
J 163106.83+050119.2		0.110	0.972	0.241	g			−0.90	d			
J 165643.94+050014.2		0.096	0.988	0.269	g?			−0.72	d?			

in column 12 indicates possibly variable objects that we found in our earlier study [13].

We thus obtained a sample of RCR objects that can be considered to be very likely variable on time scales of 6–7 years. The sample contains about 10% of all the RCR catalog objects considered.

7. CONCLUSIONS

To reveal the variable sources from the data of the “Cold” surveys, we used the technique developed in our earlier paper [13], where we derived the calibration curves and performed a detailed analysis and estimation of the relative root mean square errors for each survey. We searched for variable objects in a sample of radio sources of the RCR catalog [15] containing about 200 objects with flux density data available at three or more frequencies.

To reveal variable sources among the RCR objects of the considered sample, we estimated the long-term variability index V , the relative variability amplitude V_χ , the χ^2 probability p , and the parameters V_R and V_F .

Out of about 200 RCR catalog objects considered in this study, 41 proved to have positive long-term variability indices, suggesting their possible variability. Almost half of these sources are bright objects with flux densities above 100 mJy, and about one third of them are faint radio sources with $F \leq 40$ mJy. The distribution of spectral indices for this sample has two maxima: at $\alpha = -0.75$ and $\alpha = -0.15$. However, most of the objects with $V > 0$ have spectral indices $\alpha > -0.5$.

It can be concluded, based on the criteria proposed in [3, 34–36], that of the 41 objects with positive long-term variability indices, 15 can be considered to be reliably variable radio sources. These

sources have χ^2 probabilities $p > 0.98$, three of these objects have probabilities $p \geq 0.999$, six sources are possibly variable with the probabilities $0.95 < p < 0.98$, and 20 sources have variability probabilities in the $0.73 \leq p < 0.95$ interval.

Of the 21 most likely variable sources with $p > 0.95$, one third have flux densities above 150 mJy, seven sources have flux densities in the interval $40 < F < 100$ mJy, and seven sources have flux densities in the $20 < F < 40$ mJy interval. Most of these sources are objects with nearly flat spectra, and two objects have inverted spectra. One third of the sources have spectral indices $\alpha < -0.67$ (steep spectra).

Twenty-four of the 41 objects are variable or possibly variable in the optical range, and five objects are known variable radio sources. We obtained the light curves and spectra for the radio sources with positive long-term variability indices and for a number of “nonvariable” objects.

We thus studied about 280 radio sources of the RCR catalog. The results of our search for variable sources performed within the framework of this study and our earlier paper [13] lead us to point out that 55 radio sources have positive long-term variability indices. Fifteen of these sources meet the criterion of reliable variability (their χ^2 probabilities are $p > 0.98$), and nine objects

meet the criterion of possible variability ($0.95 < p < 0.98$). The variability probabilities of the remaining sources lie in the $0.6 < p < 0.95$ interval. Thirty-five of the 55 objects have relative variability amplitudes $V_\chi > 0.2$. Thus about 10% of all the RCR objects that we analyzed proved to be variable.

Out of 24 most likely variable sources, two are BL Lac objects, and the remaining ones are quasars (nine objects) and galaxies (10 objects).

Conspicuous is the fact that the FIRST survey flux densities of 14 out of 55 sources exceed the flux densities from the NVSS survey in what is yet another indicator of the possible variability of the sources considered. Almost half of the objects are flat spectrum sources, and about ten objects are GPS and MPS sources with the spectra peaking at GHz or MHz frequencies. Twenty-six objects out of 55 are variable or possibly variable in the optical range and five are known variable radio sources.

БЛАГОДАРНОСТИ

This work was supported in part by the Russian Foundation for Basic Research (grants no. 11-02-12036, 11-02-00489, and 12-07-00503) and the Ministry

of Education and Science France, as well as NASA/IPAC Extragalactic of the Russian Federation (state contracts Database (NED) which is operated by the no. 16.552.11.7028 and 16.518.11.7054). Jet Propulsion Laboratory, California This research has made use of the VizieR Institute of Technology, under contract catalogue access tool and the SIMBAD with the National Aeronautics and Space database, operated at CDS, Strasbourg, Administration.

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